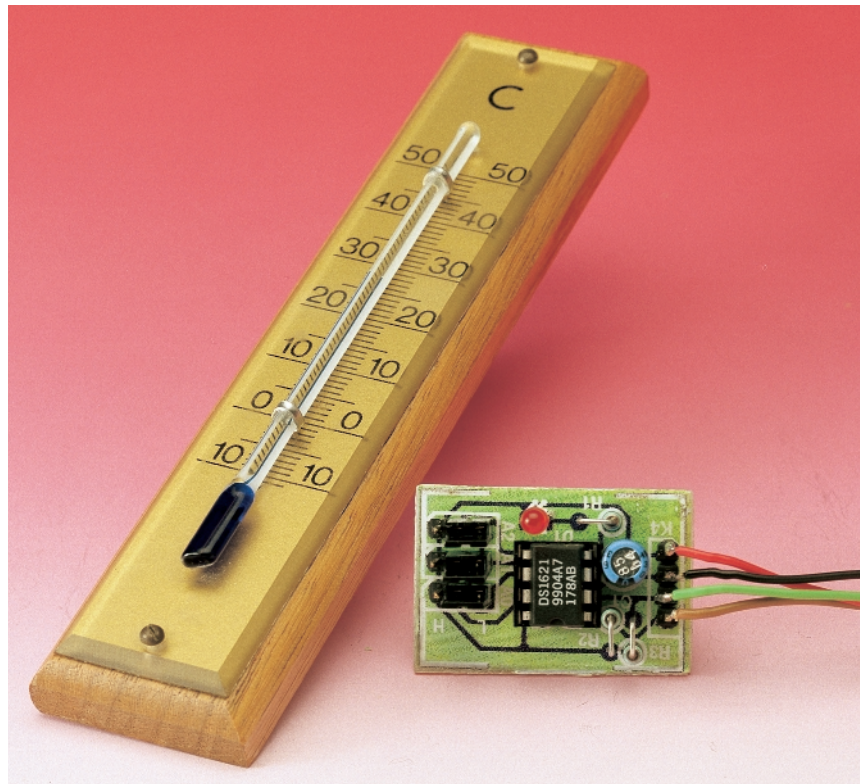


temperature measurements with a DS1621

*a smarter sensor with an
I²C-bus interface*

In many areas of daily and technical life, making temperature measurements is the most important instrumentation task. 'Intelligent' digital sensors, which can do more than just output temperature readings, are winning more ground as complements to classical analogue techniques. An example of such a sensor is the Dallas Semiconductor DS1621.



Technical specifications

No external components necessary

Temperature measurement range -55°C to $+125^{\circ}\text{C}$

Resolution 0.5°C

9-bit temperature measurement value with sign and magnitude

Conversion time 1 second

User-programmable thermostat function

Serial two-wire interface (I²C) with open-drain connections

Naturally, the main job of a modern digital temperature sensor is to determine the current temperature. It does this by measuring its own temperature, which is nearly the same as the temperature of its surroundings, and converting this analogue temperature value into a digital word that it sends to a microcontroller via a serial interface. The user doesn't have to worry about any of the analogue technology

needed for calibration, amplification of the thermal voltage with opamps, linearisation of characteristic curves and so on, since all this is either done by the chip itself or can be easily set using software. External components are thus largely unnecessary.

In addition, an intelligent sensor provides supplementary functions, such as temperature logging with the DS1615 (Elektor Electronics September

Based on an idea from
Prof. Dr. B. vom Berg

1999) or thermostatic operation, as with the Dallas Semiconductor DS1621 described in this article. The main characteristics of this IC are summarised in the Technical Specifications box. A condensed datasheet of the DS1621 may be found in this month's *Datasheets* section.

TEMPERATURE MEASUREMENT

The primary function of the DS1621 is of course measuring temperature. **Figure 1** shows the modules that are present in the IC for this purpose. The DS1621 measures the temperature by counting the number of clock cycles of produced by an oscillator with a low thermal coefficient within a given time window. The width of this window is determined by a second oscillator that has a large temperature coefficient. The counter is pre-loaded with a value that corresponds to a temperature of -55 °C. If the counter value reaches zero within the time window, the temperature register (which is also set to the value representing -55 °C) is incremented to indicate that the temperature is greater than -55 °C. The counter is clocked until it reaches zero and then restarted, as long as the time window remains open.

The counter does not always accumulate the same number of clock pulses within the time window for every degree of difference in the temperature. This is because a (variable) offset is added to the counter by the Slope Accumulator for each degree of temperature difference, in order to compensate for the non-linear behaviour of the oscillator over the temperature range. This allows a relatively high temperature resolution of 0.5 °C to be achieved.

The measured temperature is stored in the temperature register as a 9-bit value. As shown in **Table 1**, the measurement range of the DS1621 is from -55 °C to +125 °C in steps of 0.5 °C. The current temperature is output via the two-wire serial interface in response to a READ TEMPERATURE command, either as single byte with a resolution of 1 °C or as two bytes with a resolution of 0.5 °C. In the latter case the MSB is sent first, followed by the LSB, which only specifies the least significant bit of the temperature value (0.5 °C). The remaining 7 bits of the LSB are set to zero.

A trick can be used to achieve an even higher resolution. The temperature is first read, and the 0.5 °C bit (the LSB) is chopped off. The resulting value is called TEMP_READ. The value remaining in the counter when the time window closes can be read using the READ_COUNTER com-

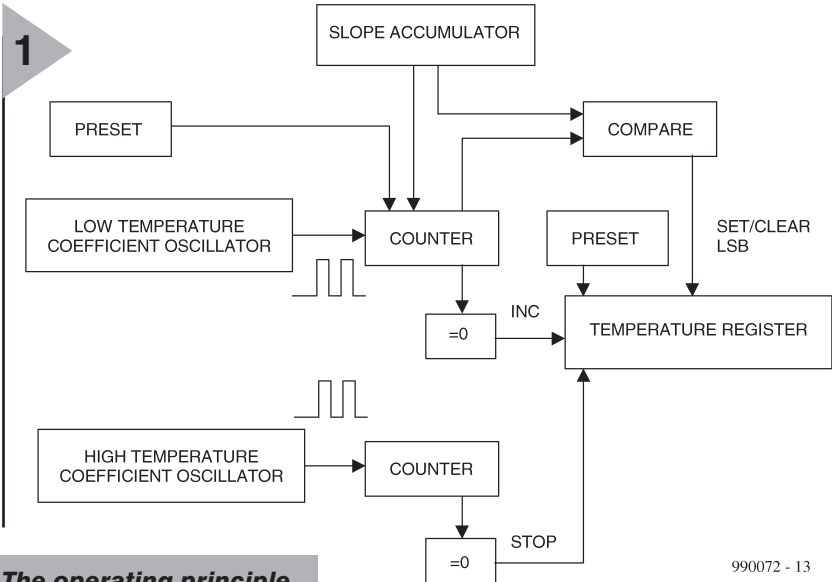


Figure 1. The operating principle for temperature measurement.

Table 1. Temperature vs. data value

Temperature in °C	Output data binary	hex
+125	01111101 00000000	7B00
+25	00011001 00000000	1900
+0.5	00000000 10000000	0080
0	00000000 00000000	0000
- 0.5	11111111 10000000	FF80
- 25	11100111 00000000	E700
- 55	11001001 00000000	C900

mand and then stored in the variable COUNT_REMAIN. The value in the Slope Accumulator can then be read using the READ SLOPE command. This value (COUNT_PER_C) is the number of counting edges per degree Celsius at the current temperature. The temperature can then be determined using the following formula:

$$\text{Temperature} = \text{TEMP_READ} - 0.25 + \frac{(\text{COUNT_PER_C} - \text{COUNT_REMAIN})}{\text{COUNT_PER_C}}$$

THERMOSTAT

As indicated in the functional block diagram of the DS1621 shown in **Figure 2**, the intelligent sensor also includes a thermostat function. Two

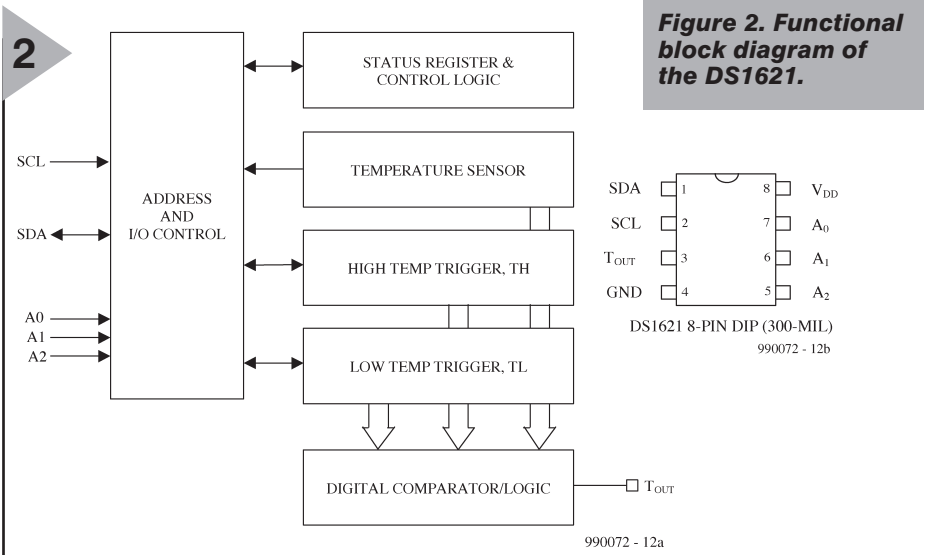


Figure 2. Functional block diagram of the DS1621.

threshold values can be programmed to create a hysteresis function. If the temperature reaches one of the preset values, rises above the upper threshold value TH or drops below the lower threshold value TL, the T_{OUT} output becomes active (High).

In addition, the DS1621 notices whenever a temperature threshold has been exceeded and sets corresponding flags in the Configuration/Status Register. This register also includes other information that controls the operating mode in a very particular application. The register is configured as follows:

DONE	THF	TLF	NVB	1	0	POL	1SHOT
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The meanings of these items are as follows:

DONE

High = conversion completed
Low = conversion active

THF (Temperature High Flag)

Set to 1 when the temperature is equal to or greater than the threshold TN. Remains active until reset.

TLF (Temperature Low Flag)

Set to 1 when the temperature is equal to or less than the threshold TL. Remains active until reset.

NVB (Non-volatile memory flag)

Active (1) whenever an EEPROM cell is being written. This can occur every 10 ms.

POL (Output Polarity bit)

Determines whether the output is active High (1) or active Low (0). Non-volatile.

1SHOT

If the 1SHOT Mode bit is High, the DS1621 performs a temperature conversion after receiving a CONVERT T command. Otherwise it operates in the normal mode, in which it continuously performs measurements and conversions. This bit is non-volatile.

COMMUNICATIONS: FORM AND CONTENT

The DS1621 works as a slave in a two-wire bus system with open-drain SDA and SCL lines and a clock rate of 100 or 400 kHz. Communication with a microcontroller or PC takes place using the well-known I²C protocol, which need not be further explained. You can find more information regarding timing, as well as all other technical specifications, in the DS1621 data sheet located at www.dalsemi.com/doccontrol/pdfs/pdfindex.html.

Every communication needs a start condition and concludes with a stop

COMPONENTS LIST

Resistors:

R1 = 1kΩ
R2, R3 = 10kΩ

Capacitor:

C1 = 100μF 16 V radial

Semiconductors:

D1 = LED, low current
IC1 = DS1621 (Dallas Semiconductor)

Miscellaneous:

K1, K2, K3 = 3-way pinheader
K4 = 4-way pinheader
Disk, contains project software, order code 996027-1

3

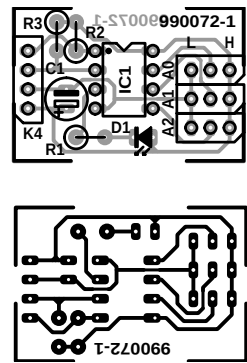


Figure 3. The printed circuit board fits into a matchbox.

bit. The DS1621 responds to each received byte with an Acknowledge.

The start bit is always followed by an address byte, which consists of four bits set to the value 1001 and three bits that are determined by the levels applied to the address inputs A2, A1 and A0. The final bit determines the communications direction (R/W).

The address byte is followed by a command byte. The DS1621 recognises the read and write commands listed in Table 2, including their codes. The two conversion commands are finished when the address and command bytes have been sent, but one or two data bytes follow the command byte for the write commands. With the read commands, the structure is somewhat more complicated, since the IC must be provided with a second address byte to set the R/W bit to Read. The one or two data bytes can be read only after this has taken place.

Dallas Semiconductor has a free Demonstration Kit available for the DS1621. This monitors the sensor IC in a temperature logging application. The three temperature values (measurement and hysteresis) are displayed with a resolution of 0.1 °C or 0.5 °C.

The user can set the threshold values for the thermostat output and the acquisition interval in seconds, enable direct output of the measured values to a file and select a temperature display in Fahrenheit or Celsius, or as a 2-D or 3-D graphic. The software supports three parallel ports and eight hardware addresses for the DS1621.

The software for this kit, which runs under Windows 3.xx and higher, may be downloaded from this Internet site: [ftp://ftp.dalsemi.com/pub/thermal/ds1621k.zip](http://ftp.dalsemi.com/pub/thermal/ds1621k.zip)

If you do not have access to the Internet, you can obtain the software on a floppy disk from our Readers Services under order number 996027-1.

HARDWARE

As the name suggests, a kit includes a printed circuit board with the sensor and all other components that are needed to connect to the parallel port of a PC. However, any electronics hobbyist would rather construct this minimal amount of hardware himself and thus avoid the stress of ordering the kit. All that you need is the printed circuit board shown in Figure 3, the listed components and a hot soldering iron.

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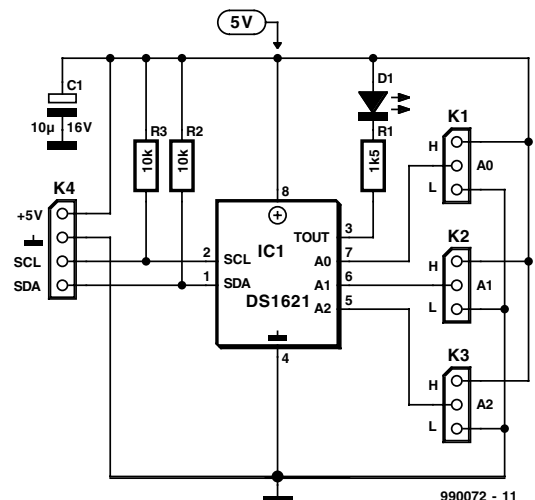


Figure 4. No surprises here: the LED indicates that the threshold has been exceeded.

Table 2. DS1621 command set

Command	Description	Value (hex)	Following bytes
<i>Temperature measurement commands</i>			
Read Temperature	Reads the latest temperature value from the temperature register	AA	reads two data bytes
Read Counter	Reads the remainder in the time window counter	A8	reads one data byte
Read Slope	Reads the value in the Slope Accumulator	A9	reads one data byte
Start Convert T	Starts a temperature conversion	EE	no data
Stop Convert T	Stops a temperature conversion	22	no data
<i>Thermostat function commands</i>			
Access TH	Reads/writes the upper threshold value from/to the TH register	A1	reads/writes two data bytes
Access TL	Reads/writes the lower threshold value from/to the TL register	A2	reads/writes two data bytes
Access Config	Reads/writes data from/to the Configuration register	A1	reads/writes one data byte

The circuit on this board, which you can assemble in a few minutes, corresponds to the schematic diagram shown in **Figure 4**, which needs only a brief explanation.

The address of the DS1621 is set by jumpers K1 through K3. The board can

be very easily connected to the I²C interface of a microcontroller system via K4.

However, connecting the board to a parallel port of a PC, in order to run the Dallas Semiconductor program, is another story. For this, you will need a

parallel I²C interface, such as that published in the February 1996 issue of *Elektor Electronics*, with the accompanying software (Readers Services order number **950063-C**).

(990073-1)

CORRECTIONS & updates

I²C interface for the printer port

March 1999, Supplement p. 10-11 (990034-1)

If the software keeps producing error messages despite proper operation of the hardware, pins 10 (ACK) and 13 (SLCT) of K1 should be connected to ground.

EEDTS Pro

Series, June 1999 – October 1999 (980055)

Constructors and users are advised that the author, S. de Vries, has set up a dedicated website at:

www.gironet.nl/home/editspro

Mr. De Vries may also be reached by email on:

editspro@gironet.nl

Poor Man's Shortwave radio

October 1999, p. 42-45 (990068-1)

On the PCB, the centre pin of filter MF11 has no ground connection. This causes insufficient selectivity. The error may be corrected by fitting a small piece of wire as indi-

cated in the drawing.

If you use a capacitor with a pin spacing of 7.5mm in position C13, the ground connection has to be made with a small piece of wire.

